INTRODUCTION

Guided Missiles, self-propelled aerial projectiles, usually containing conventional or nuclear explosives, guided in flight towards a target either by remote control or by internal mechanisms. Guided missiles vary widely in size and type, ranging from large strategic ballistic missiles with nuclear warheads to small, portable rockets carried by foot soldiers. Although most are military weapons with explosive warheads, others may carry scientific instruments for gathering information within or above the Earth's atmosphere.

Guided missiles consist of three separate systems: power source, guidance and control mechanism, and warhead or payload. Power sources normally are either self-contained rocket motors or air-breathing jet engines, but may also be airfoils or outside booster charges from ramp or tube launchers. The type of guidance and control system employed depends on the type of missile and the nature of the target. Inertial guidance systems sense the position of the flight path in relation to a fixed target; other guidance systems use a variety of more active sensors to help direct the missile towards a moving objective. Payloads are generally warheads (bombs) designed for specific missions, from piercing armour plate to destroying entire urban areas.

Before World War II guided missiles were limited to experimental, pilotless aircraft controlled by radio. During the war, however, rapid technological advances in such fields as aerodynamics, electronics, rocket and jet propulsion, radar, servo-mechanisms, inertial guidance and control systems, and aircraft structures, coupled with the intensive search for better weapons, led to the construction, testing, and finally mass production of the modern guided missile.

GUIDANCE AND CONTROL

Missiles are guided towards targets by remote control or by internal guidance mechanisms. Remote-control missiles are linked to a human or mechanical target locator through trailing wires, wireless radio, or some other type of signal system. Internal guidance mechanisms

have optical, radar, infrared, or some other type of sensor that can detect heat, light, or electronic emissions from the target. Most missiles have some type of movable fins or airfoil that can be used to direct the course of the missile towards the target while in flight.

The inertial guidance systems of ballistic missiles are more complex. Missile velocity, pitch, yaw, and roll are sensed by internal gyroscopes and accelerometers, and course corrections are made mechanically by slightly altering the thrust of the rocket exhaust by means of movable vanes or deflectors. In larger rockets, small external jets are also used to alter direction.

TYPES OF MISSILES

Guided missiles today are grouped into five launch-to-target categories: surface-to-surface, surface-to-air, air-to-surface, air-to-ground, and air-to-air. “Surface” in each case signifies on as well as below the surface of the land or sea. Missiles may also be grouped by their area of operation. Tactical missiles are used by military forces in direct combat on and above the battlefield; support missiles are employed behind the main battle area; and strategic missiles are designed for intercontinental warfare.

Missiles may also be differentiated by their flight characteristics. Aerodynamic missiles are supported in flight by air pressure around their wing and body surfaces, similar to conventional piloted aircraft, whereas ballistic missiles depend solely on their internal power source, usually a rocket engine, to remain airborne. Aerodynamic missiles normally travel on a straight-line or flat trajectory towards their target, and ballistic missiles are usually surface-to-surface weapons that follow curved or arched trajectories similar to that of an artillery projectile.

MISSILE COMPONENTS

Guided missiles are made up of a series of subassemblies. The various subassemblies form a major section of the overall missile to operate a missile system, such as guidance, control, armament (warhead and fuzing), and propulsion. The major sections are carefully joined and

connected to each other. They form the complete missile assembly. The arrangement of major sections in the missile assembly varies, depending on the missile type.

The guidance section is the brain of the missile. It directs its maneuvers and causes the maneuvers to be executed by the control section. The armament section carries the explosive charge of the missile, and the fuzing and firing system by which the charge is exploded. The propulsion section provides the force that propels the missile. The complete missile guidance system includes the electronic sensing systems that initiate the guidance orders and the control system that carries them out. The elements for missile guidance and missile control can be housed in the same section of the missile, or they can be in separate sections.

GUIDANCE SYSTEMS

The purpose of a guidance subsystem is to direct the missile to target intercept regardless of whether or not the target takes deliberate evasive action. The guidance function may be based on information provided by a signal from the target, information sent from the launching ship, or both. Every missile guidance system consists of two separate systems-an attitude control system and a flight path control system. The attitude control system maintains the missile in the desired attitude on the ordered flight path by controlling it in pitch, roll, and yaw (fig. 1- 16). This action, along with the thrust of the rocket motor, keeps the missile in stabilized flight. The flight path control system guides the missile to its designated target. This is done by determining the flight path errors, generating the necessary orders needed to correct these errors, and sending these orders to the missile's control subsystem. The control subsystem exercises control in such a way that a suitable flight path is achieved and maintained. The operation of the guidance and control subsystems is based on the closed-loop or servo principle (fig. 1-17). The control units make corrective adjustments to the missile control surfaces when a guidance error is present. The control units also adjust the wings or fins to stabilize the missile in roll, pitch, and yaw. Guidance and stabilization are two separate processes, although they occur simultaneously.

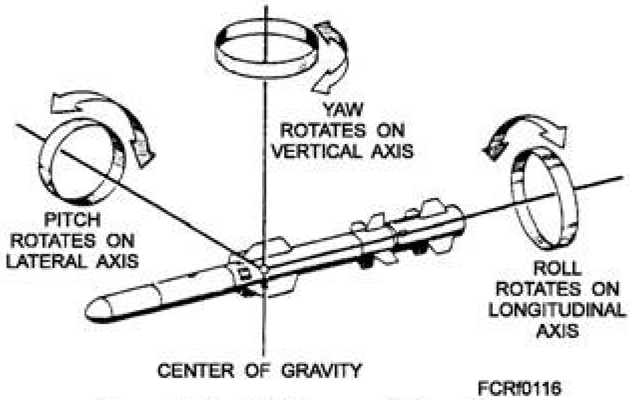


Figure 1-16.—Missile axes: pitch, roll, yaw.

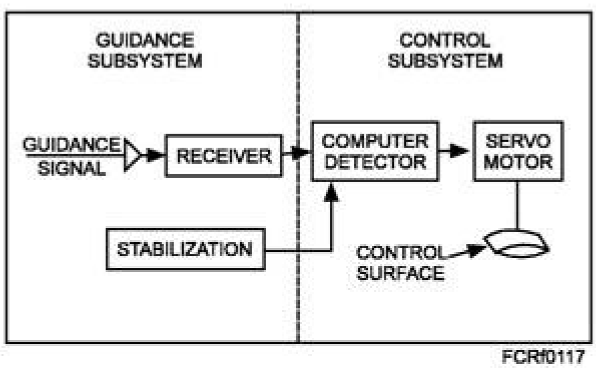


Figure 1-17.—Basic missile guidance and control systems.

Phases of Guidance

Missile guidance is generally divided into three phases

The three phases are boost, midcourse, and terminal. Not all missiles, however, go through the three phases.

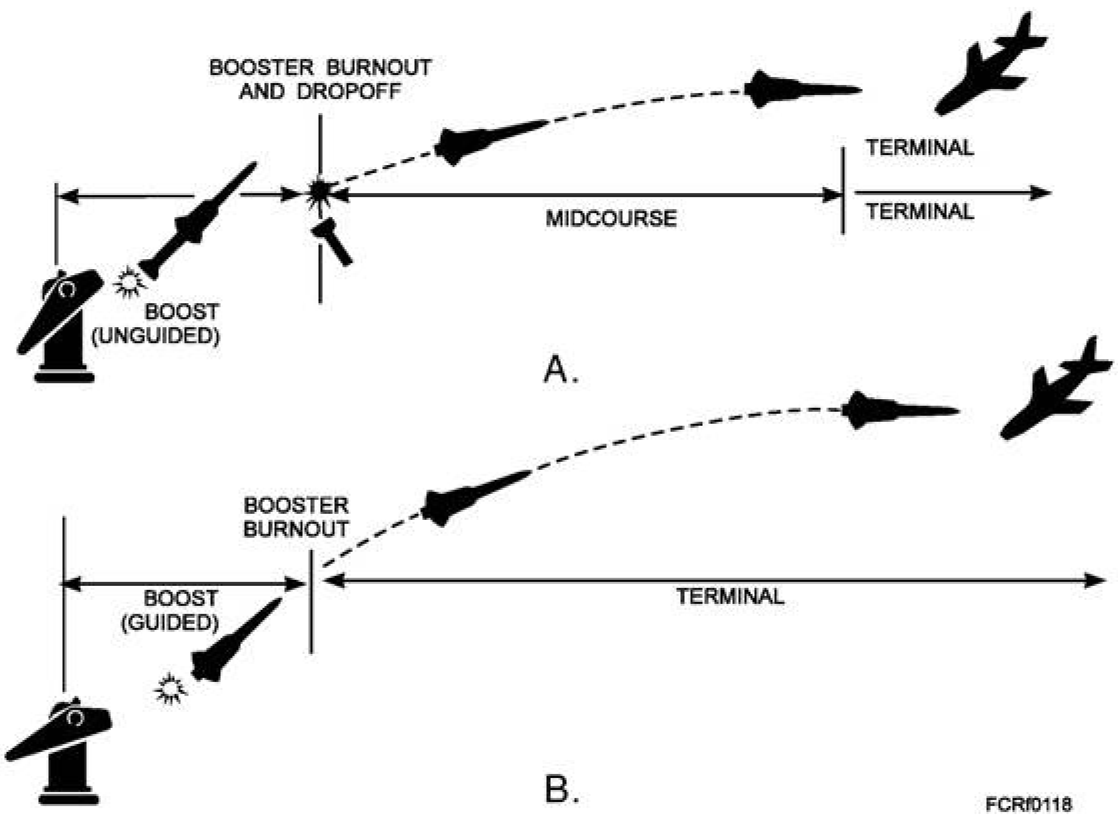
INITIAL (BOOST) PHASE.-Navy surface-launched missiles are boosted to flight speed by the booster component (which is not always a separate component) of the propulsion system. The boost period lasts from the time the missile leaves the launcher until the booster burns up its fuel. In missiles with separate boosters, the booster drops away from the missile at burnout (fig. 1-18, view A). Discarding the burnt-out booster shell reduces the drag on the missile and enables the missile to travel farther. SMS missiles with separate boosters are the STANDARD (ER) and HARPOON.

The problems of the initial (boost) phase and the methods of solving them vary for different missiles. The method of launch is also a factor. The basic purposes, however, are the same. The missile can be either pre-programmed or physically aimed in a specific direction on orders from the fire control computer. This establishes the line of fire (trajectory or flight path) along which the missile must fly during the boosted portion of its flight. At the end of the boost period, the missile must be at a precalculated point.

There are several reasons why the boost phase is important. If the missile is a homing missile, it must "look" in a predetermined direction toward the target. The fire control computer (on the ship) calculates this predicted target position on the basis of where the missile should be at the end of the boost period. Before launch, this information is fed into the missile.

When a beam-riding missile reaches the end of its boosted period, it must be in a position where it can be captured by a radar guidance beam. If the missile does not fly along the prescribed launching trajectory as accurately as possible, it will not be in position to acquire the radar guidance beam and continue its flight to the target. The boost phase guidance system keeps the missile heading exactly as it was at launch. This is primarily a stabilizing function.

During the boost phase of some missiles, the missile's guidance system and the control surfaces are locked in position. The locked control surfaces function in much the same manner as do the tail feathers of a dart or arrow. They provide stability and cause the missile to fly in a straight line.



MIDCOURSE PHASE.-Not all guided missiles have a midcourse phase; but when present, it is often the longest in both time and distance. During this part of flight, changes may be needed to bring the missile onto the desired course and to make certain that it stays on that course. In most cases, midcourse guidance is used to put the missile near the target, where the final phase of guidance can take control. The HARPOON and STANDARD SM-2 missiles use a midcourse phase of guidance.

TERMINAL PHASE.-The terminal or final phase is of great importance. The last phase of missile guidance must have a high degree of accuracy, as well as fast response to guidance signals to ensure an intercept. Near the end of the flight, the missile may be required to maneuver to its maximum capability in order to make the sharp turns needed to overtake and hit a fast-moving, evasive target. In some missiles, maneuvers are limited during the early part of the terminal phase. As the missile gets closer to the target, it becomes more responsive to the detected error signals. In this way, it avoids excessive maneuvers during the first part of terminal phase.

Guidance and Control Section

There are a number of basic guidance systems used in guided missiles. Homing-type, air-launched, guided missiles are currently used. They use radar or infrared homing systems. A homing guidance system is one in which the missile seeks out the target, guided by some physical indication from the target itself. Radar reflections or thermal characteristics of targets are possible physical influences on which homing systems are based. Homing systems are classified as active, semiactive, and passive.

INERTIAL GUIDANCE

An inertial guidance system is one that is designed to fly a predetermined path. The missile is controlled by self-contained automatic devices called accelerometers.

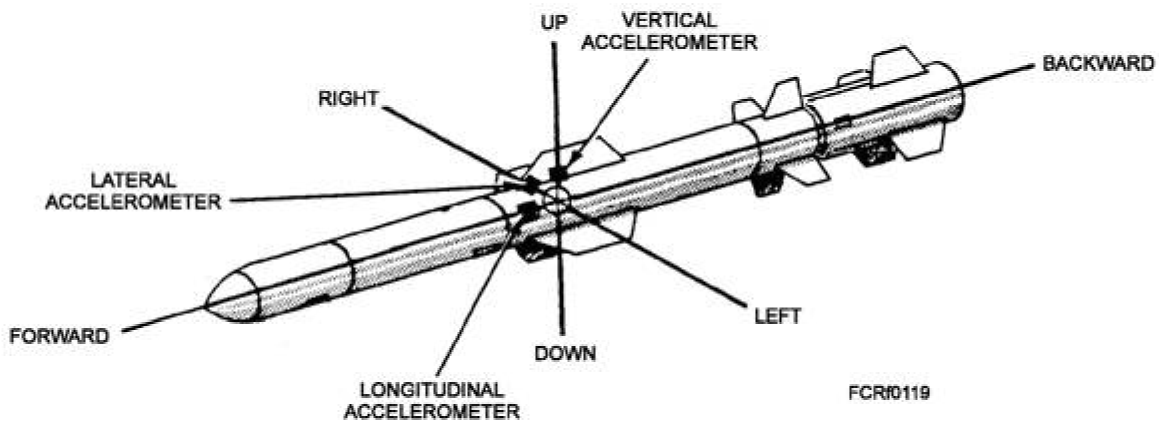
Accelerometers are inertial devices that measure accelerations. In missile control, they measure the vertical, lateral, and longitudinal accelerations of the controlled missile (fig. 1-19). Although there may not be contact between the launching site and the missile after launch, the missile is able to make corrections to its flight path with amazing precision.

During flight, unpredictable outside forces, such as wind, work on the missile, causing changes in speed commands. These commands are transmitted to the missile by varying the characteristics of the missile tracking or guidance beam, or by the use of a separate radio uplink transmitter. This data is taken by onboard computers and converted onto precise position of the missile.

Lately, however, inertial systems have been combined with GPS (Global Positioning System) to navigate missiles more accurately. This combination is used in ICBMs (Inter-continental Ballistic Missiles).

However, even with the best inertial systems available, missiles suffer from a phenomenon called drift. This is measured in distance (meters) per hour. For example, during the making of the Tomahawk Cruise missiles it was determined that even with the inertial navigation system, it would have a drift of 900 meters per hour. This essentially means that if the missile

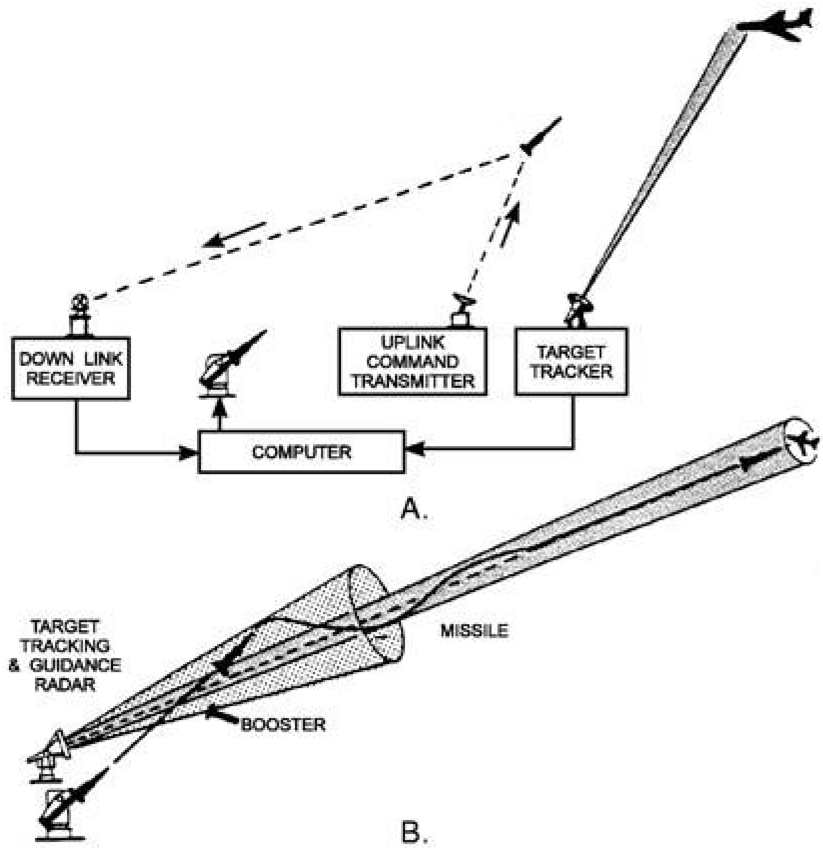
flew for one hour, it could miss the target by as much as 900 meters! Further, while ICBMs travel at sonic and supersonic speeds, smaller Cruise's speed was subsonic. So, the chances of missing the target are higher.



BEAM-RIDER GUIDANCE

A beam-rider guidance system is a type of command guidance in which the missile seeks out the center of a controlled directional energy beam. Normally, this is a narrow radar beam. The missile's guidance system receives information concerning the position of the missile within the beam. It interprets the information and generates its own correction signals, which keep the missile in the center of the beam. The fire control radar keeps the beam pointed at the target and the missile "rides" the beam to the target

As the beam spreads out, it is more difficult for the missile to sense and remain in the center of the beam. For this reason, the accuracy of the beam-rider decreases as the range between the missile and the ship increases. If the target is crossing (not heading directly at the firing ship), the missile must follow a continually changing path. This may cause excessive maneuvering, which reduces the missile's speed and range. Beam-riders, therefore, are effective against only short- and medium-range incoming targets.



HOMING GUIDANCE.

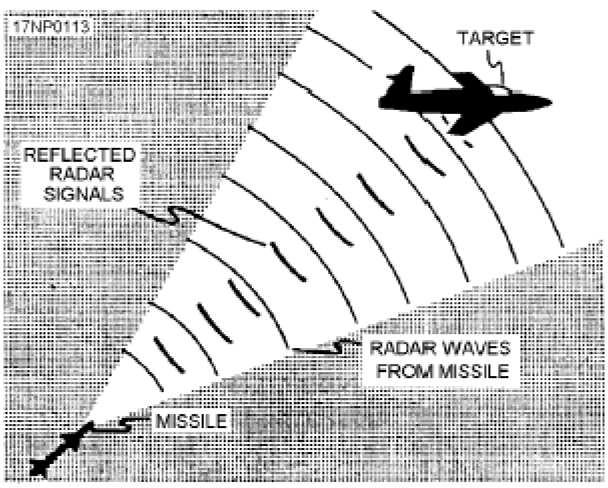
Homing guidance systems control the path of the missile by means of a device in the missile that detects and reacts to some distinguishing feature of (or signal from) the target. This may be in the form of light, radio, heat, sound waves, or even a magnetic field. The homing missiles use radar or RF waves to locate the target while air-to-air missiles sometimes use infrared (heat) waves

Since the system tracks a characteristic of the target or energy reflecting off the target, contact between the missile and target is established and maintained. The missile derives guidance error signals based on its position relative to the target. This makes homing the most accurate type of guidance system, which is of great importance against moving air

targets. Homing guidance methods are normally divided into three types:, active homing, semi-active homing, and passive homing

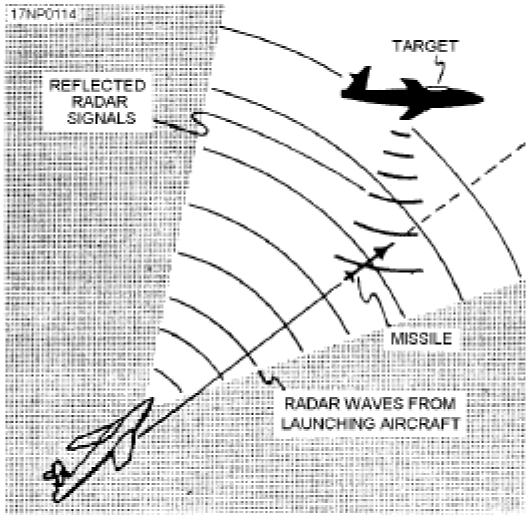
ACTIVE

In the active homing system, target illumination is supplied by a component carried in the missile, such as a radar transmitter. The radar signals transmitted from the missile are reflected off the target back to the receiver in the missile. These reflected signals give the missile information such as the target's distance and speed. This information lets the guidance section compute the correct angle of attack to intercept the target. The control section that receives electronic commands from the guidance section controls the missile’s angle of attack.



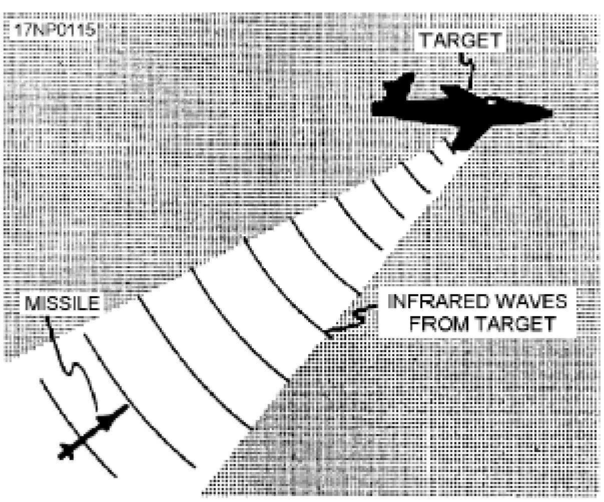
SEMIACTIVE

In the semiactive homing system, the missile gets its target illumination from an external source, such as a transmitter carried in the launching aircraft. The receiver in the missile receives the signals reflected off the target, computes the information, and sends electronic commands to the control section.



PASSIVE

In the passive homing system, the directing intelligence is received from the target. Examples of passive homing include homing on a source of infrared rays (such as the hot exhaust of jet aircraft) or radar signals (such as those transmitted by ground radar installations). The missile receiver receives signals generated by the target and then the missile control section functions in the same manner.



OPTRONIC MISSILE GUIDANCE SYSTEMS

Advantages of these optronic missile guidance systems over radar guidance systems include high resolution, the use of only passive operating mode (in other words, no signals are emitted), and a compact size and low weight of the onboard equipment. To sum up, they feature high accuracy, low signature to radar systems, and overall simplicity.

The optronic guidance system includes highly-sensitive small-size sensors and ground-based information systems for receiving and processing images, generating target designation and reference data, and finally, to promptly transmit the data to the missile launch sites. At present, the optronic guidance systems are based on state-of-the-art optronic units, high-speed computers and sophisticated software. The optronic guidance system is used in the U.S.-made Tomahawk cruise missiles.

Optronically guided cruise missiles are more efficient in overcoming anti-missile defense zones, and, furthermore, do not deviate from their target by more than a few meters

TERCOM GUIDANCE SYSTEM

As a solution to the drift problem, a guidance system called TERCOM (Terrain Contour Matching) is used. Though very old as a technology (first tested in 1961 onboard an aircraft), this could not become popular because of the payload size of the computational resources needed for TERCOM was huge at that time. With faster yet smaller computer systems, this technology was re-looked at for the purpose of missile navigation. Here is how TERCOM works.

The system uses radar to scan the ground/terrain that the missile is passing over. The terrain data is compared to the digital maps stored in the computer on the missile. These stored digital maps are of the area along the intended flight path of the missiles and are gathered by satellites and reconnaissance planes. If a drift is noticed, the inertial navigation system is corrected and a course correction is made to put the missile back on path. This process is used a number of times to ensure that the missile does not drift too much before a flight correction is made. Owing to this, the projectiles fall within 50 meters of their target.

An added advantage of TERCOM is that the missiles fly very low, almost skimming the ground. Coupled with their small size and radar cross-section, low infrared signature, they become virtually undetectable by enemy radar. Also, a flight path can be input into the onboard system to make the missile ‘fly around’ known enemy defenses!

Another alternative is to use GPS to complement the navigational data computed by inertial system. GPS is based on an array of low-earth satellites. Computers onboard the missile communicates with these satellites to accurately determine their instantan- eous location. GPS is a system that is widely used nowadays for navigation, both in defense and civil applications

POLYPHEM FIBRE-OPTIC GUIDED MISSILE SYSTEM

This system uses infra-red imaging for high precision targeting by day and night against mobile or fixed targets. The images from an infrared camera in the nose of the missile are transmitted through a fibre-optic cable to a firing station, where they are automatically analysed, processed and displayed to the weapon system operator. The operator can then send the missile guidance instructions via the cable.

The system uses advanced image processing algorithms, electro-optical converters and radio links. The firing station has a Global Positioning System (GPS) Navstar navigation reference unit, a north seeking device and a command, control, communications and information (C3I) system interface. For mission planning, the firing station stores a digitised map and displays the map during missile flight. For some mission applications a dual monitor system can be used.

Themain part of the guidance system is the infrared imager. It is mounted on a gyro-stabilized dual axis platform. The platinum silicide (PtSi) focal plane array provides high resolution images for target detection, discrimination and destruction, and for battlefield reconnaissance and damage control assessment. The quality of the image allows the operator to detect the targets at ranges up to 8km. The navigation system comprises an Inertial Measuring Unit (IMU) supported by an altimeter and GPS Navstar receiver and ensures that the missile follows a predetermined trajectory into the designated target area.

The fibre-optic transmission system provides simultaneous optical transmission of video data from the missile to the ground station and of command data from the ground station to the missile at data rates of more than 200MB/s. As well as a high data transmission rate, the fibre optic links provide immunity to active jamming and electro-magnetic interference.

PHASES OF RADAR OPERATION

The three sequential phases of radar operation (designation, acquisition, and track) are often referred to as modes.

Designation Phase

During the designation phase, the fire-control radar is directed to the general location of the target.

Acquisition Phase

The fire-control radar switches to the acquisition phase once its beam is in the general vicinity of the target. During this phase, the radar system searches in the designated area in a predetermined search pattern until it either locates the target or is redesignated.

Track Phase

The fire-control radar enters into the track phase when it locates the target. The radar system locks on to the target during this phase.

Guidance systems used in missiles

MINUTEMAN III Missile

The Minuteman III is a solid-fueled, intercontinental ballistic missile (ICBM), which the U.S. Air Force first deployed in large numbers in beginning in the late 1960s. The guidance

system, contained in a ring located between the upper stage and the missile's re-entry vehicle, was a crucial part of Minuteman and a key to its success as a weapon. Signals from this ring traveled down the side of the missile to the rocket nozzles, where they controlled the direction and cut-off of thrust.

The Guidance system consists of three basic parts. One is a set of gyroscopes that maintain a stable platform, regardless of whatever motions the missile goes through. Within that platform are also sensors that measure acceleration. This information is sent to the second part, a digital computer, which translates that data into information about the missile's current location and velocity. Prior to launch, the computer is given information about the point of launch, the gravitational field over which it will fly, and the intended target. By comparing the actual velocity with the missile's intended trajectory, the computer sends correcting signals to the third part of the system, the control electronics that control the rocket nozzles.